DOCUMENT RESUME

ED 342 190 EC 300 949

AUTHOR	Okolo, Cynthia M.
TITLE	Classroom Uses of Instructional Technology: Recommendations for Future Research and Related Activities.
INSTITUTION	COSMOS Corp., Washington, DC.
SPONS AGENCY	Special Education Programs (ED/OSERS), Washington, DC.
PUB DATE	Sep 90
CONTRACT	HS89021001
NOTE	73p.; For related documents, see EC 300 948-951.
PUB TYPE	Guides - General (050) -- Viewpoints (Opinion/Position Papers, Essays, etc.) (120)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Classroom Techniques; Cognitive Processes; *Disabilities; *Educational Technology; Elementary Secondary Education; Financial Support; Government Role; *Instructional Effectiveness; Instructional Innovation; Microcomputers; Problem Solving; Reading Comprehension; *Reading Instruction; Reading Research; *Research and Development; Research Needs; Special Education; Systems Approach; Teacher Role; Technological Advancement; Theory Practice Relationship; Word Processing; *Writing Instruction; Writing Research
IDENTIFIERS	*Office of Special Education Programs

ABSTRACT

This paper proposes four scenarios to guide future research investments by the federal Office of Special Education Programs in classroom uses of instructional technology for learners with disabilities. Sets of research and development activities to promote effective use of technology are proposed for: (1) reading instruction; (2) writing instruction; (3) problem solving instruction; and (4) distributed cognition. Introductory material provides the rationale for choosing these themes. A 1- to 3-year agenda is suggested for research on reading and writing. Stressed for research on reading instruction are the use of technology to support reading comprehension instruction and the use of technology with students of differing skill and age levels. Also recommended is development of new instructional technology tools in reading. Research in writing instruction should address questions concerning the conditions under which word processing helps writing, facilitating writing collaboration, and instructional effects with disabled students. Increased development of writing instruction tools is also recommended. A 3- to 8-year agenda is suggested for research on problem solving and cognition. Proposed research questions for the problem solving area include identifying domain specific problem solving skills and behaviors and integration of problem solving instruction into content area subjects. Recommended for research into distributed cognition are questions about knowledge representation in technology based systems and instruction for optimal use of knowledge systems. (158 references) (DB)

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CLASSROOM USES OF INSTRUCTIONAL TECHNOLOGY: RECOMMENDATIONS FOR FUTURE RESEARCH AND RELATED ACTIVITIES

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September 1990

Contract # HS89021001
Office of Special Education Programs
U. S. Department of Education

This Paper was commissioned by COSMOS Corporation in support of their program sector analysis (PSA) for the Office of Special Education Programs.

CONTENTS

I. INTRODUCTION

Computer-based instructional technology captured educators' attention in the mid 1970s, amidst promises that its widespread use would revolutionize education. Special educators were among the first group of teachers to enthusiastically endorse the possibilities computers offered. Indeed, research regarding the efficacy of instructional technology with handicapped learners and low achievers has demonstrated that computers and other electronic technologies can be used to successfully deliver, supplement, and manage instruction (Fuchs, Hamlett, Fuchs, Stecker, and Ferguson, 1988; Majsterek and Wilson, 1989; U.S. Congress, Office of Technology Assessment (OTA), 1988; Schmidt, Weinstein, Niemic, and Walberg, 1985-86; Swan, Guerrero, Mitrani, and Schoener, 1990; Woodward, Carnine, Collins, 1988). However, fifteen years later, most educators agree that instructional technology has not lived up to its promises (LaFrenz and Friedman, 1989). Several factors can help explain why instructional technology seems to have lost its momentum.

First, the fanfare with which instructional technology was introduced to educators and parents undoubtedly fostered naive claims and unrealistic expectations (Cohen, 1987; Cuban, 1986). Maddux (1988) notes that a pervasive mystique seemed to characterize many early uses of instructional technology: "all we need to do is place a computer and a child in the same room and wonderful things will happen" (p. 8). For example, initial word processing enthusiasts claimed that, by removing the paper-and-pencil burden, educators could unleash the creativity that lurked inside students with disabilities (e.g., Hagen, 1984; Rosegrant, 1985). However, research soon showed that mere access to a word processor did not guarantee improved writing (Hawisher, 1986). While it was true that students made more revisions to text when provided with word processing capabilities, these revisions tended to be surface-level changes that affected features such as spelling, punctuation, and length of text rather than ones that improved the quality of writing (e.g., Daiute, 1986a).

A second factor, often unrecognized in discussions of instructional technology, is the limited resources available to work the promised technological miracles. In 1983, national data collected in the "School Uses of Microcomputer Survey" (Becker, 1983) indicated that schools had few computers, relative to total school enrollment. Desirous of giving all students access to computer experiences, schools tended to spread computers among as many students as possible. In the small amount of time each student had at the computer, s/he was most likely to get a taste of computing by participating in a drill-and-practice activity, copying or creating a simple BASIC program, or playing a computer game (Becker, 1990a). One can hardly expect that such limited computer experiences would have a substantial impact on teaching and learning. Minimal changes took place over the next few years. The "Second National Survey of Instructional Uses of School Computers" reported that technology remained divorced from day-to-day classroom instruction. Computers were used primarily to provide enrichment and variety to the classroom routine or to teach computer literacy (Becker, 1985).

Only recently have schools been able to amass the quantity of computers that may be needed to impact instruction. Becker (1990a), in describing data collected in the 1989 "Computers in Education" survey conducted by the International Association for the Evaluation of Educational Achievement (IEA), reports that the "typical" school in this country now has about 45 computers; a significant increase from the 21 computers per school documented in the 1985 survey (Becker, 1985). Roughly twice as many teachers in the 1989 survey reported using computers for instruction than did their counterparts in 1985. Moreover, Becker reports that the proportion of schools with 15 or more computers has increased from 24 percent in 1985 to 57 percent in 1989. He concludes that 15 computers per school constitutes a critical mass; with this many computers located in one class or lab, whole class instruction is now feasible if students work in pairs.

A third factor that has prevented more widespread use of technology in the schools is insensitivity to the constraints that teachers encounter in schools and classrooms. The educational system has been chastised for the "narrow" and unimaginative ways in which it utilizes technology (Russell, 1986; Turkel and Podell, 1984) and educators have been criticized for their unwillingness to use new hardware and software and their lack of interest in professional development and change (cf. Hass, 1990). As Apple and Jungck (1990) note, pressures from a variety of constituencies have resulted in a tightly controlled curriculum in which teachers are expected in accomplish more in a climate of diminishing resources and support. Although technology has been touted as a time-saver, teachers have reported that the initial stages of utilizing a new technology are extremely challenging and time-consuming (OTA, 1988; Wiske, Zodhiates, Wilson, Gordon, Harvey, Krensky, Lord, Watt, and Williams, 1988). Moreover, as curricula become more regimented and more states utilize standardized test scores to gauge student progress, teachers will be reluctant to utilize technology applications that are not closely aligned to curricular and assessment objectives (Lampert, 1988; Wiske, Shepard, and Niguidula, 1987).

To date, most demonstrations of successful instructional technology applications have taken place in laboratories or controlled experimental settings. Although this research provides essential illustrations of technology's potential, it is only a first step in ensuring that technology has a positive impact on teaching and learning as it occurs on a day-to-day basis. Teachers rarely have the level of support that is built into most research and demonstration projects. Even when districts employ school- or district-level technology coordinators, these educators are often assigned circumscribed roles that allot them little time to support others in their implementation of instructional technology (Barbour, 1986; Lieber and Cosden, 1989; McGinty, 1987; Zorfass, Persky, and Remz, 1990).

When researchers have examined how technological innovations are implemented under "natural" classroom conditions, they find enormous variability. Given access to identical hardware, software, and training; teachers will "appropriate" technology and use it in ways that are consistent with their own goals, styles, and physical settings (Amarel, 1983; Harvey, Kell, and Drexler, 1990; Newman, 1989); producing different results across settings. Thus, instructional technology can be likened to a chameleon; depending on its setting and the person using it, its appearance may change. It should thus come as no surprise that the effects of instructional technology on teaching and learning are difficult to evaluate and synthesize.

A final factor that has dampened enthusiasm for instructional technology is the limited nature of the outcome measures used in many studies. After reading reports of technology implementation projects, one cannot help but wonder about the gap between teachers' perceptions of technology's impact and the often negligible changes in traditional indicators of student performance (e.g., Drexler, Harvey, and Kell, 1990) Many studies have spanned only a few weeks or months. Because students with disabilities can be expected to learn at slower rates and need more intensive instruction than their non-handicapped peers; short-term interventions can hardly be expected to produce significant changes. Pre- to post-test gains on achievement tests have been the typical metric by which technology outcomes are evaluated. However, many tests are inappropriate for atypical populations and are insensitive to the gains one can expect from students who learn at a slower pace (McDermott and Watkins, 1983). Moreover, achievement tests address only one realm of potential technology-related outcomes. Indeed, some recent research suggests that outcomes such as enhanced intrinsic motivation (Lepper and Malone, 1987; Malouf, 1985-86; Okolo, Hinsey, and Yousefian, in press; Rieber, 1990) and more adaptive attributions for successes and failures (Okolo, in preparation; Swan, Mitrani, Guerrero, Cheung, and Schoener, 1990) may be facilitated through instructional technology. Changes in students' perceptions of learning and self-efficacy may be even more important and enduring than the changes in skills or knowledge typically measured by achievement tests. However, affective states may be difficult to document until better assessment techniques are developed.

Given the problems cited above, it is not surprising that instructional technology has not lived up to its initial promises. Future research and related activities should be grounded in a thorough understanding of the factors that have limited instructional technology's utilization to date. Rather than assuming that these factors will restrict instructional technology to its present state of implementation, the recommendations set forth in this paper will address ways in which these factors can be acknowledged, addressed, or avoided.

A. Criteria for Recommending Future Investments

The purpose of this paper is to construct four scenarios to guide future investments in instructional technology. These scenarios encompass sets of activities that can promote effective uses of instructional technology for learners with disabilities and are organized around the following four themes: (a) instructional technology and reading instruction, (b) instructional technology and writing instruction, (c) instructional technology and problem-solving instruction, and (d) instructional technology as distributed cognition. These four themes focus on classroom uses of instructional technology; systems changes are addressed in a companion paper.

Confronted with the task of choosing four themes from among the many unanswered questions about classroom uses of instructional technology, one must make choices. I have attempted to ground my choices in extant research and will highlight studies that support each theme. I also have been guided by what I believe must be the paramount consideration in decisions about future instructional technology investments. **If instructional technology is to have optimal impact, it must be used by teachers in a systematic manner as part of their ongoing instructional programs.** In other words, instructional technology must be integrated with the curriculum. The importance of linking instructional technology to curricular needs has been documented through the technology integration projects funded by the Office of Special Education (Macro Systems, 1989; Panyan and Hummel, 1988; Zorfass et al., 1990) and in other research programs (e.g., Winkler, Shavelson, Stasz, Robyn, and Feibel, 1985).

I applied four other criteria to help me prioritize recommendations. First, I invoked the principle of educational necessity (Torgesen and Young, 1983). By focusing on "educational necessities," or the most critical problems faced by teachers and students (Torgesen and Young, 1983), instructional technology can have a significant impact on the teaching and learning process. All four themes address important instructional needs of special education teachers and their students.

Next, I considered the principle of educational uniqueness (Clark, 1985). Technology can enable teachers and students to accomplish goals that are infeasible or impossible with traditional instructional approaches. Some of the research and related activities encompassed in each scenario address ways that technology can extend existing instructional approaches and promote the accomplishment of new knowledge and skills.

Third, I choose themes that can help build a vision of multiple ways in which instructional technology can improve special education services. Despite the increasing investment schools have made in hardware and software, drill-and-practice activities remain the most common instructional technology application in elementary schools and special education classrooms (Becker, 1990a; Becker and Sterling, 1987). Educators need more information and guidelines about how technology can be used to achieve a broad range of educational goals (Kerr, 1990; Plomp, Steerneman, and Pelgrum, 1988; Wiske, Zodhiates, Wilson, Gordon, Harvey, Krensky, Lord, Watt, and Williams, 1988). The four scenarios depicted in this paper cover a spectrum of instructional technology applications and should add to existing information about potential classroom uses.

Finally, I have eschewed the principle of technology for technology's sake. In order to avoid naive promises and unwarranted overgeneralizations, technology cannot be viewed as an end in itself. Rather, its role must be considered in relation to educational needs, educational practices, and principles of effective instruction. Extant research must be used to delineate effective practices that may be implemented in new and perhaps better ways through instructional technology. The recommended activities in this paper are organized around substantive (e.g., reading instruction, problem solving), rather than technological themes (e.g., hypermedia, videodiscs). Although each thematic area has its share of unresolved questions and theoretical controversies, sufficient theoretical and empirical work exists within each theme to guide decisions about how technology can contribute to instruction.

B. Themes Considered But Not Recommended

A number of potential themes met at least some of the above criteria but were not recommended. Narrr ving the field of worthy topics to four necessitated establishing priorities and choosing themes that I believe will yield the greatest benefits for students with disabilities. Undoubtedly, one could argue that the topics described below are worthy of further exploration and, in some cases, they can be subsumed under the four scenarios I have recommended. My rationale for not choosing each of these topics as the prim.ry focus of research and related activities are outlined below.

Descriptive Studies of Technology Use

Numerous surveys and observational studies have documented how regular and special educators perceive and use technology (e.g., Becker, 1985; 1987; 1990a; Cosden, 1988; Hanley, Clark, and White, 1984; Lewis, Dell, Lynch, Harrison, and Saba, 1987; Mokros and Russell, 1986; Rieth, Bahr, Okolo, Polsgrove, and Eckert, 1988; Sandals and Hughes, 1988). Descriptive studies provide an important picture of the "state-of-the-practice" in instructional technology and, given their quantity and quality, currently constitute a sufficient base upon which to recommend future research investments that will broaden the ways that technology has been used and viewed over the past decade.

General Attitudes toward Technology

Students' and teachers' attitudes have been examined in a number of studies. Earlier research indicated that some teachers had unfavorable attitudes toward technology and were anxious about using it (e.g., Jay, 1981; Norris and Lumsden, 1984). However, attitudes toward technology appear to be extremely malleable; when provided with opportunities to use technology, teachers and students tend to develop positive attitudes. Thus, lack of experience may be the best explanation for the negative attitudes found in earlier studies. Recent research suggests that special educators and their students have favorable attitudes toward instructional technology (e.g., Gardner and Bates, 1989; Okolo and Owen, 1990a; Okolo, Rieth, and Bahr, 1989; OTA, 1988). Factors other than attitudes, including lack of resources and time constraints described above, present more formidable barriers to the implementation of instructional technology. Thus, attitudes in and of themselves do not seem worthy of further study, although researchers may wish to examine attitudinal variables in the research and related activities recommended below.

Instruction in Basic Skills

Basic skill instruction lends itself to implementation in the drill-and-practice activities that have characterized much of educational computing. A highly productive line of research has examined how instructional technology can be used to teach basic skills. Effective technology-based interventions have been developed to promote automaticity in math computation (Goldman and Pellegrino, 1987; Hasselbring, Goin, and Bransford, 1987; Rouse and Evans, 1985; Trifiletti, Frith, and Armstrong, 1984), decoding (Jones, Torgesen, and Sexton, 1987; Torgesen, 1986; Warren and Rosebery, 1988), and word recognition (e.g., Cohen, Torgesen, and Torgesen, 1988; Lesgold, 1983; Roth and Beck, 1987; Torgesen, Waters, Cohen, and Torgesen, 1988). To a lesser extent, researchers have explored ways in which technology can enhance students' vocabulary knowledge (McKeown and Beck, 1988; Sternberg, Powell, and Kaye, 1983). This line of research has produced knowledge and products that have substantially enhanced basic skill instruction for learners with disabilities. It has also contributed to our understanding of effective instructional design, both on and off computers.

Although basic skills are important, relatively little attention has been paid to ways in which technology can deliver instruction in higher-order skills such as reading comprehension, written expression, and problem solving. Given this disparity, it seems prudent to shift the focus of future efforts from basic skills to the higher-order skills that are necessary for fluid and skilled performance in a variety of instructional domains.

Programming Instruction

Programming instruction has been a popular but controversial computer-based instructional activity (Johanson, 1988). Programming instruction, most often in BASIC or Logo, has been designed not only to teach programming itself, but also to teach problem-solving skills (e.g., Dalby and Linn, 1985; Minsky, 1970; Papert, 1980). Intuitively, programming instruction seems likely to promote problem-solving skills by virtue of the activities it entails and the approach it requires. Programmers must specify tasks or problems, develop a plan, sequence information, generate and test hypotheses, work with precision, and attend to details (Palumbo, 1990). Despite a plethora of studies and heated controversy regarding methods and philosophies (e.g., Becker, 1987; Pea, 1987; Papert, 1987; Walker, 1987); there is no convincing evidence to support the claim that programming instruction enhances general problem-solving skills (Palumbo, 1990; Pea, 1984). The search for ways to improve students' problem-solving skills through technology should continue. However, in light of the extant evidence, it is recommended that future efforts to improve problem-solving skills be based in contexts other than programming instruction.

Expert Systems and Computer-Managed Instruction

These topics represent potentially important uses of instructional technology that can improve instruction for students with disabilities and enhance educators' efficiency and efficacy. Both applications are designed to help educators and students make decisions; thus, they presume that the knowledge base upon which decisions are made can be embodied in a technology-based system. However, many decisions and practices in special education are based on a less-than-complete knowledge base. Consider the rampant disagreements about how to define learning disabilities or how to measure adaptive behavior. Moreover, the primary factors that influence educators' decisions may not be amenable to technology-based representations. Referral practices, judgments about the least restrictive environment for an individual child, or assessments of a student's motivation for learning are best explained by qualitative factors such as teacher tolerance, parental aspirations, or clinical judgment. Furthermore, Hativa's research with computer-managed instructional systems (Hativa, 1988; Hativa and Lesgold, 1990; Hativa, Shapira, and Navon, 1989) demonstrates that they often make inaccurate decisions about and prescriptions for students with disabilities. Finally, the cost associated with developing and field-testing these systems and the hardware and software needed to operate them may be prohibitive.

The factors outlined above will continue to plague the development of expert systems and computer-managed instructional applications in the near future. Thus, I have not recommended that these topics as a sole focus for future OSEP investments. However, some of the development activities recommended below could support further work with expert systems and computer-managed instructional applications.

Motivational Attributes of Instructional Technology

I believe this topic is an important one; in fact, it is my fifth choice for future OSEP investments. As discussed above, one of the most important benefits of instructional technology may be its impact on students' self-efficacy and motivation to learn. Research which delineates the conditions under which instructional technology has a positive effect on motivational variables could facilitate the development of instructional technology applications that not only improve achievement but also enhance motivation. Because this paper is limited to four themes, I have attempted to suggest how motivational variables can be investigated within each scenario.

C. Organization of the Scenarios

The following chapters will depict four scenarios to guide future research investments in classroom uses of instructional technology. Two scenarios are presented within each timeframe and each scenario is organized around a substantive theme, as described above. Each scenario opens with a brief introduction and overview. Within each scenario, recommendations for research topics with a rationale and expected benefits.

Questions are posed in conjunction with each set of recommendations. These questions represent, to my mind, issues or topics that are most worthy of investigation. I have provided theoretical, empirical, or pragmatic information to justify the importance of each question. However, the reader should bear in mind that these questions do not constitute an exhaustive or restrictive list of the topics that could be examined under each set of activities. Undoubtedly, other researchers could pose and justify issues that are as or more important.

II. RESEARCH THEMES FOR A ONE TO THREE YEAR AGENDA

Research themes for the first timeframe focus on the use of technology for literacy instruction. Literacy, defined broadly as proficiency in reading and written expression, is undoubtedly the paramount goal of our nation's educational system. Because students with disabilities are most often referred to special education for difficulties with reading and written expression, literacy instruction is a primary goal of special education services (Ysseldyke and Algozzine, 1983). Research that address the use of technology to support literacy instruction will address one of the most important instructional needs faced by educators and students with disabilities.

Two scenarios are presented below for the themes technology and reading instruction and technology and writing instruction. The focus of recommended research activities in both scenarios is on applied studies that examine the manner in which technology can facilitate specific instructional outcomes in typical classroom settings. In the proposed research activities, technology is viewed as playing an "enhancement" rather than "replacement" role (Hofmeister and Thorkildsen, 1989), and the primary goal of recommendations is to further the "state-of-the-practice" rather than the "state-of-the-art" in instructional technology. I am recommending that research activities within the first timeframe be supported for up to five years.

In contrast, the development activities recommended in the first two scenarios may be accomplished in three years. They focus on the generation and evaluation of technological tools that can either deliver or support specific types of literacy instruction and are intended to advance the state-of-the-art by providing teachers and students with new instructional technology applications.

A. Scenario One: Technology and Reading Instruction

No other instructional domain seems to generate as much controversy as reading. Perennial disagreements continue regarding the nature of proficient reading, the manner in which reading should be taught, and the relative emphasis that particular skills should receive. Technology is unlikely to resolve these disagreements, but it offers considerable potential to support a variety of reading skills and methods.

Recommended Research and Development

Two sets of research and development activities are recommended below. First, two research themes are proposed to investigate ways in which technology can support reading instruction as it occurs in typical classroom settings. The second recommendation is for development activity that can stimulate the production and evaluation of technology-based tools to enhance students' reading skills. From this line of research, students with disabilities and their teachers would benefit by promoting effective uses of technology in reading instruction for a variety of students in different instructional settings. Results and products from these projects could guide developers and manufacturers in their attempts to produce technology applications that are efficacious and consistent with curricular goals and classroom practices. Findings can also provide an important base for future preservice and inservice teacher preparation efforts.

Research Activity: Technology in Support of Reading Instruction

To date, information about how technology can be used to support reading instruction is fragmented and often limited to data about the impact of a specific CAI program on the reading skills of a particular group of students. The research themes should focus on: 1) examine the use of technology to support reading comprehension instruction; and 2) the use of technology with students of differing skill and age levels. The research efforts should be integrated into a comprehensive of reading instruction and its effects on the teaching and learning process. Emphasis should be placed on the utilization and examination of commercially-available technology, rather than on the development of new hardware and software applications. The following questions comprise a set of topics that warrant investigation under this research theme.

How can instructional technology be used to support instruction in reading comprehension skills? As described above, a number of studies have demonstrated that instructional technology can successfully supplement and reinforce instruction in the basic skills of decoding, word recognition, and vocabulary knowledge. Although many experts agree that basic skills are critical components of reading (e.g., Anderson, Hiebert, Scott, and Wilkinson, 1985); a basic-skills-only focus does not directly address the important task of deriving meaning from connected text. Reading comprehension is a complex task that draws not only on lower-level skills such as decoding, word recognition, and vocabulary knowledge; but also entails higher-order skills and strategies. Effective comprehenders make extensive use of their background knowledge, demonstrate awareness of different purposes for reading and different patterns of text organization, construct and verify predictions as they read, use context clues to aid comprehension, and monitor whether or not they understand (Bransford, Stein, and Vye, 1982; Merrill, Sperber, and McCauley, 1981; Paris, 1981; Pearson and Camperell, 1981). Learners with disabilities often need explicit instruction in these skills in order to become proficient readers.

Researchers and curriculum developers have paid increasing attention to comprehension instruction in the past decade and a number of promising approaches have been developed and field-tested. Palinscar and Brown (1984) developed the activity of reciprocal teaching, which entails a structured dialogue between the teacher and students as they attempt to understand segments of text. The dialogue is guided by the activities of summarization, question generation, clarification, and prediction. Initially, the teacher leads the dialogue and models the four comprehension activities. Eventually, students take turns leading the dialogue. The reciprocal teaching approach has been used successfully with reading and learning disabled students (Brown and Palinscar, 1982; 1987; Palinscar and Brown, 1984).

Researchers at the University of Kansas have developed a learning strategies curriculum, the first strand of which is designed to help students comprehend written materials. Five strategies in this strand focus on reading comprehension: the Visual Imagery Strategy, the Self-Questioning Strategy, the Paraphrasing Strategy, the Visual Aids Strategy, and the Multipass Strategy. Instruction in each strategy follows an explicit acquisition-to-generalization sequence and promotes active student involvement. Research has demonstrated that instruction in these strategies can improve the reading skills of children and youth with mild disabilities (Clark, Deshler, Schumaker, and Alley, 1984; Lenz, Schumaker, and Deshler, in press; Schumaker, Denton, and Deshler, 1984; Schumaker, Deshler, Alley, and Denton, 1982).

Despite the importance of reading comprehension skills and the promising approaches developed by Palinscar and Brown and the University of Kansas researchers, among others, little guidance is available to suggest how educational technology can support this aspect of reading instruction. Comprehension activities such as reciprocal teaching and learning strategies instruction do not lend themselves to traditional CAI formats. However, newer technologies such as hyper-media and videodiscs may offer potential avenues for supporting a broader variety of reading instruction. Videodiscs have been used to create "macrocontexts"; or contexts that are sufficiently broad and rich to facilitate instruction in a variety of skills and content areas. Video macrocontexts can supply the background knowledge that students with disabilities often need to successfully construct meaning from text. Vye, Rowe, Kinzer, and Risko (1990) describe an experimental curriculum that integrated social studies content with reading comprehension activities. The videos "Young Sherlock Holmes" and "Oliver Twist" were used as macrocontexts to provide students with rich and authentic descriptions of 19th century England upon which to build instructional activities and subsequent understanding. When compared to a traditional curricular approach, the macrocontext-based program had a significant impact on students' recall, vocabulary usage, and comprehension and produced the greatest effects for low-achieving students (Risko et al., 1989; Vye et al., 1990).

Text-based adventure games, in which the user assumes the role of a character and is confronted with problems to be solved, represent another avenue for improving reading comprehension skills. Adventure games such as Snoopers Troops and Where in the World is Carmen Sandiego entail self-directed reading and problem-solving situations and are widely used in educational settings. Students appear to enjoy text-based adventure games, and thus are motivated to use them for reading practice. However, they may learn little from the activities themselves (Forsyth and Lancy, 1987; Wiebe and Martin, 1990). Characteristics of adventure games that mitigate their effectiveness include: (a) sparse and disjointed text, (b) an emphasis on problem solving, rather than reading instruction, (c) minimal assistance to the user, who must abandon the game if s/he can't solve the problems, (d) obscure and non-intuitive commands for game play, (e) requirements for strategic game play, which are often unclear, unused, or irrelevant to educational goals, and (f) graphics that do not accurately portray the phenomena they are supposed to depict (Grabe and Dosmann, 1988; Wiebe and Martin, 1990). Improvements in these features or in the manner with which text-based adventure games are used within the reading curriculum may enhance their efficacy.

In summary, a variety of methods have been developed to teach reading comprehension skills, including reciprocal teaching and learning strategies instruction. However, little is known about whether these approaches can be delivered through or supported by instructional technology. Emerging technologies, such as hypermedia and videodiscs, may offer considerable advantages for enhancing students' background information and vocabulary knowledge. Moreover, adventure games may offer a motivating format for the practice and exercise of reading comprehension skills. To date, researchers have only begun to explore the types of reading comprehension skills and strategies that technology can support and its efficacy in doing so.

<u>How can instructional technology best support reading instruction at different developmental levels</u>? The nature of reading instruction must vary with the skill level and characteristics of the learner. For example, the goals and activities of reading instruction for learning disabled first graders will be significantly different than those for adolescents with severe disabilities. Whereas phonics instruction may be most important for beginning readers at risk for learning disabilities, functional sight vocabulary may be critical for moderately disabled adolescents. Consequently, the manner in which instructional technology supports reading instruction must vary with reading goals and learner characteristics. However, little is known about how technology can support reading instruction for different goals and learners. Although some systematic research has examined instructional technology's role in early reading instruction for at-risk students (e.g., Educational Testing Service, 1984; Harvey et al., 1990); the majority of research has focused on elementary school students with learning disabilities. Educators could benefit from more extensive information regarding ways in which instructional technology can support reading instruction for a broader variety of activities and students.

<u>How can instructional technology facilitate the provision of reading instruction to students with disabilities in mainstream settings</u>? Instructional technology may offer alternatives to placing students with disabilities into more restrictive settings for specialized reading instruction. Instruction presented through interactive technologies, such as computer-based instructional programs and computer-interfaced videodiscs, can enable the classroom teacher to tailor instruction to individual needs in a manner heretofore infeasible. Students who need additional practice or instruction can review or reuse these programs as many times as necessary with minimal teacher assistance. As discussed earlier, macrocontexts can provide

disabled students with background information to facilitate comprehension.

Researchers who have studied applications of instructional technology in regular classrooms often comment on the improved social integration and academic achievement of students with disabilities (e.g., Brown, 1990; Weir, 1989; Winn and Coleman, 1989). These reports are anecdotal, however; few systematic studies exist of the conditions under which technology can facilitate integration. Research activities that address this question could offer useful strategies to facilitate the provision of instruction in the least restrictive environment.

<u>How can synthetic speech be used to support reading instruction</u>? Synthetic speech is a critical element in any instructional software program that mirrors the reading process in which text is translated to speech. However, many issues about its use remain unresolved. Speech synthesizers vary widely in the intelligibility of their speech output; predictably, the most intelligible systems are also the most expensive. Poor-quality speech may violate the integrity of a computer-based instructional program. Students may invest more mental effort in understanding the speech than in learning the decoding principles or the vocabulary words intended by the developer. Given the expense involved in producing highly intelligible speech output, developers and educators will have to sacrifice intelligibility for cost. But to what extent? What is the optimal cost vs. intelligibility ratio? What types of supporting information and contexts can be provided within or outside a computer-based program to enhance the intelligibility of low-cost speech output? Researchers have demonstrated that speech output becomes more intelligible to a user over time (Hoover, Reichle, Van Tassell, and Cole, 1987; Pisoni and Hunnicutt, 1980; Rhyne, 1982). To date, however, we know little about the types of familiarization experiences that can improve speech intelligibility.

Other questions that could enhance the efficacy of computer-based reading programs relate to the manner in which students access speech within a program. Many existing programs (e.g., Beck, McKeown, and Roth, 1987; Higgins and Boone, 1989; Rosegrant and Cooper, 1983-84) permit the student to decide when to access speech output for assistance in "reading" unfamiliar text. When we observed learning disabled students using Beck et al.'s, (1988) vocabulary program, we found that rarely accessed its speech output capabilities (Okolo and Owen, 1990b). Students not only had difficulty remembering the multiple key sequence required to access speech, they were unaware of their need for the assistance speech output could provide. Wise (personal communication, March, 1990) notes students may require explicit instruction to improve their awareness of the advantages of using speech output. How should programs be structured so that students can easily access speech output? How much control should students be given over the use of speech output and how can students be taught to effectively monitor their need for the assistance that speech can provide?

A final issue of interest, which has been raised in studies conducted by Wise et al., (1989), relates to the level at which speech output should be provided in programs that teach decoding skills. Is speech output most helpful at the word, syllable, or phonemic level? Speech output at each of these levels will contain differing amounts of contextual information to aid intelligibility, and thus the minimally acceptable quality of speech may vary. How intelligible does speech need to be at each level in order to facilitate learning? Which level of feedback is most efficacious for improving decoding skills and what impact does output at each level have upon students' ability to generalize decoding skills to new materials and situations?

<u>What are the effects of using instructional technology to provide reading instruction to students with disabilities</u>? This critical question must be investigated at multiple levels. First, researchers and program developers must examine the impact that instructional technology has on the reading skills it purports to teach. Gains in reading skills should be measured through experimental-control group comparisons wherever possible (Becker 1990b). Characteristics of the instruction provided in both experimental and control groups should be thoroughly described. Researchers should avoid "stacking the deck" by

comparing instructional technology with traditional approaches that are known to be ineffective for students with disabilities. Control groups should receive instruction of a similar quality to that provided via technology. Otherwise, valid conclusions cannot be drawn about the relative advantages of instructional technology.

Data also should be collected regarding the impact of instructional technology on student motivation, attitudes, and perceptions. Examples of variables that researchers may want to examine include student interest in and willingness to read, self-awareness of reading skills and strategies, attributions for success and failure in reading, and self-efficacy in reading. Although more difficult to measure, changes in these variables have important implications for judgments about the impact on instructional technology on students' present and future reading proficiency.

A third topic for examination is students' perceptions of technology-based learning activities; particulary when they incorporate game-like or video-based formats. Salomon (1984) contends that the way learners perceive a medium and the qualities they attribute to it influence the depth at which information is processed. He examined differences in students' perceptions of text-based and TV-based versions of an instructional activity. Students reported that TV was more realistic; a feature often attributed to video-based instruction (The Cognition and Technology Group at Vanderbilt, 1990). They viewed themselves as more efficacious with TV than print and attributed success with print to their own ability or effort. In contrast, success with TV was attributed to the "easiness" of the activity. Both Salomon (1984) and Krendl (1986) found that students think they learn more from media which they prefer and find easy. However, when performance is measured, students actually learn more from media they prefer less but perceive as harder.

These results suggest that students may be predisposed to invest less mental effort when activities are perceived as "easy," and thus may actually learn less when instruction is presented through formats such as videodiscs, multi-media, and games. Perceptions of these media may mitigate their impact unless students are taught how to learn from them and use them efficaciously. Further research on student perceptions of technology-based instruction is needed to more fully explicate these issues.

A final area for investigation is the effect of instructional technology on teachers' approaches to reading instruction and their perceptions of students. Although existing research suggests that technology has a minimal impact on the way in which teachers provide instruction, the majority of studies to date have been of limited duration and have investigated only computer-assisted instructional activities. Little is known about how extended use of technologies such as videodisc-based instruction may affect the instructional process. Researchers may wish to examine whether or not technology increases student interaction and collaboration; affects teachers' perceptions of their instructional role, instructional planning, and goals for reading instruction; or enhances teachers' sense of efficacy and professionalism (Herman, 1988). Changes in teachers' perceptions of student ability may be another fruitful area for exploration. As discussed above, a number of researchers have presented enticing examples of disabled students who no longer appear different from their classmates when participating in technology-intensive instructional environments (e.g., Brown, 1990; The Cognition and Technology Group at Vanderbilt, 1990; Weir, 1989). However, most of these examples are based on incidental and post-hoc observations of reactions to an individual student's behavior. Case studies, interviews, or systematic observations of these phenomena could significantly enhance our understanding of whether or not instructional technology has a broad effect on classroom instruction.

What type of preparation and support do teachers need to implement instructional technology for reading instruction? Eventual decisions about the feasibility and impact of utilizing instructional technology to support reading instruction must include consideration of the preparation that teachers need to implement these innovations and the types of support they need to maintain them. Answers to these questions should be based on extended study of the manner in which particular instructional technology applications or programs are used in a typical classroom setting over an extended period of time. In addition to collecting data regarding the impact of technology on students, teachers, and the instructional process; researchers should also provide data regarding the types and cost of hardware and software resources that are required. Information about the technical support needed to implement a program and cost-effective ways of providing that support should also be collected. Researchers should describe ways in which they prepared teachers to utilize instructional technology for reading instruction and may wish to examine the relative efficacy of different approaches. As teachers implement technology, researchers should track the problems they encounter and their emerging needs for information or support.

Development Activity: Development and Evaluation of Technology-Based Instructional Tools for Support of Reading Comprehension Instruction

Resources are needed to stimulate the development of new instructional technology tools that can be used to support or provide reading instruction. Research efforts should focus on the development and field-testing of new applications that embody principles of effective reading instruction and address critical skill needs of students with disabilities.

As discussed above, technology offers considerable promise for enhancing the delivery of reading comprehension instruction and consequently improving students' reading comprehension skills. In addition to a vehicle for instructional delivery, technology also can also be viewed as a tool that can provide on-line help to students in their efforts to construct meaning from text. Weizenbaum (1976) defines a technological tool as "a model for its own reproduction and a script for the reenactment of the skill it symbolizes." Thus, technological tools not only facilitate the accomplishment of a task, they can model effective ways of performing that task. Salomon (1988) purports that technological tools can be internalized by the learner and subsequently used as cognitive tools if they extend the learner's cognitive activities in novel and important ways, are within the learner's capabilities to assimilate, and are explicit in their operation. The notion of cognitive tools is a powerful one that has significant implications for the instruction of students with disabilities.

Warren and Rosebery (1988) describe a computer-based program called the Reader's Assistant that embodies characteristics of a cognitive tool. The program is designed to promote comprehension as a problem-solving activity and contains two types of technological tools. The first is a procedural tool that prompts the student to enter questions, summaries, and predictions about a text segment, in much the same way a teacher or peer would guide a student during reciprocal teaching. The program also contains enabling tools that provide students with on-line help in decoding and defining unfamiliar words and extending vocabulary knowledge. Enabling tools are intended to help students overcome the "bottlenecks" to comprehension often experienced by disabled readers.

Higgins and Boone (1989) developed and field-tested hypertext reading materials that contain three levels of technological tools. At the first level, a reader can request information to supplement his/her existing background knowledge about the text, including related pictures, animated graphic sequences, definitions, synonyms, and computer-generated speech. Second-level tools include strategies for decoding unknown words and for understanding relationships between words and phrases in the text. Third-level tools encompass activities that promote comprehension, including literal and inferential questions, paragraph summaries, main idea matching, and re-reading for specific details. Although these materials have not undergone extensive field-testing, preliminary results indicate that program has a significant effect on the reading abilities of primary-age students who are at-risk for referral to special education services.

With the exception of the programs described above, few technology-based tools have been developed to support students' reading comprehension. These research efforts can support the transfer of a broader range of comprehension skills and strategies into technological tools. Moreover, investigation of the conditions under which technological tools become cognitive tools should comprise a significant component of the activities supported by the proposed competition. The programs developed by Warren and Rosebery and Higgins and Boone are examples of technological tools that can enhance students' comprehension of specific texts, i.e., the ones built into the computer program. Applications such as these can have a much broader impact if the supports, prompts, and information they contain provide students with cognitive tools that can then be applied to any text. Extent research warns us of the minimal probability that students will autonomously intuit the strategies embodied in these tools, internalize them, and generalize their use across varied tasks and settings (Perkins, 1985). Undoubtedly, students will need explicit instruction to transform technological tools into cognitive tools (Haynes, Kapinus, Malouf, and MacArthur, 1984). Developers should examine not only the ways in which technological tools can best support comprehension of text, but also the manner in which they should be structured and the type of instruction necessary to promote their generalization.

When field-testing new instructional tools, formative evaluation should comprise a substantial component. Developers should pay careful attention to the user-technology interface and the manner in which students interact with the technological tool. Systems with little tolerance for input errors or stray responses may be particularly inappropriate for learners with disabilities, who may be unable to adapt to stringent response requirements (Hativa and Lesgold, 1990). Observations and interviews can help developers analyze how students understand features such as screen layout, icons, speech, help prompts, feedback, and response input (Char, 1989).

Working prototypes of technological tools should be subjected to extensive field-testing in classroom settings. Char (1989) proposes that field testing address questions such as the following. How can this tool be used with individuals, small groups, and large groups?

How well does this tool reinforce, complement, or extend classroom learning activities? How can educators assess the benefits of this tool for student learning and progress? What type of management problems does this tool introduce and how can these be resolved? Comprehensive evaluation is critical for iteratively improving the operation of these applications and increasing the likelihood that they will be utilized in classrooms.

B. Scenario Two: Technology and Writing Instruction

Written language proficiency has important implications for students' school success, vocational flexibility, and independent functioning (Englert et al., 1988). Researchers have found that students with disabilities exhibit both quantitative and qualitative deficits in written language skills. In comparison to non-disabled peers, students with disabilities produce fewer sentences and words (Mykelbust, 1973; Nodine, Barenbaum, and Newcomer, 1985). They also display difficulties in monitoring and editing their compositions (Englert, Raphael, and Anderson, 1986) and are less sensitive to organizational structures for comprehending and composing text (Englert et al., 1986; Englert and Thomas, 1987; Nodine et al., 1985). Clearly, written expression is an important skill and a critical instructional need for many students with disabilities.

From systematic research on technology and written instruction, results can promote the utilization of instructional technology for written expression instruction. Increased use of technology may not only increase the degree to which an important but often neglected skill is provided to students with disabilities, it may also improve the quality of written expression instruction. Technology offers opportunities for educators to confront written expression goals that have been difficult to achieve, such as enhanced motivation for writing, individualized guidance during the revision process, and collaboration among disabled and nondisabled students. Research findings should generate needed information about ways in which educators can integrate word processing, telecommunications, and networking into the language arts curriculum and the conditions under which these activities are effective. Data regarding the expense of implementing and maintaining these applications should assist teachers and administrators in making decisions about their relative costs and benefits. Finally, these research efforts can provide data and products that will be useful to developers, publishers, and teacher educators.

Research: Technology in Support of Effective Writing Instruction

Over the past decade, researchers and curriculum developers have made substantial progress in developing strategies and materials upon which comprehensive programs of written instruction can be built (Graham and Harris, 1988). Cognitive strategy instruction and collaboration are central features in most of these approaches. Cognitive strategies have been developed to guide the planning, generating, and revisions stages of writing. For example, Graham and Harris (1988) describe a three-step strategy that students can use to plan and write opinion essays. Englert et al., (1988) delineate an expository writing program titled "Cognitive Strategies Instruction for Writing." One feature of this program is the use of "think sheets" that provide students with explicit organizational and thinking strategies for each stage of the writing process. The University of Kansas Learning Strategies Curriculum contains a strand of strategies for facilitating written expression that include sentence, paragraph, and theme writing strategies and an error-monitoring strategy (Deshler and Schumaker, 1986; Schumaker, Nolan and Deshler, 1985; Schumaker and Sheldon, 1985).

Collaboration between teacher and students and among students is a second feature of many written expression instruction programs. Collaboration reinforces the communicative aspect of writing (Englert et al., 1988) and enables the teacher to model writing strategies and processes for students (Isaacson, 1989). Graham and Harris (1988) recommend that teachers should "develop a sense of community during the writing period" by encouraging students to share their writing and assist each other in the editing process. Englert et al., (1988) contend that collaboration not only assists students in the revision process but also affirms the writer's role as informant, reinforces the relationship between writing (author) and reading (audience), and improves students' comprehension- monitoring skills. Glaser (1990) notes that collaboration "extends the locus of metacognitive activity" by exposing learners to views other than their own, consequently challenging their initial assumptions and helping them clarify their initial understanding.

As described above, instructional technology proponents have on occasion assumed that writing abilities would improve by virtue of access to technology. Researchers are now exploring the more productive question of how technology can be integrated with writing instruction to enhance that instruction and improve student skills. Answers to the questions discussed below could advance the use and efficacy of instructional technology as a major component of written expression. Funding is needed for programs of research that would permit these questions to be explored in classroom settings over time.

Under what conditions does word processing help students with disabilities to become better writers? Word processing comprises the predominant use of technology in language arts classes. The IEA survey (Becker, 1990a) found that an increasing amount of school computer time is spent on keyboarding and word processing, particularly at the high school level. Data regarding the impact of word processing on students' written expression skills is equivocal. As Cochran-Smith, Kahn, and Paris (1989) point out, however, there can be no single answer to the question "do students write better when they use word processors?" Results depend on the capabilities of the user, the learning and teaching context, and the capabilities of the word processing hardware and software.

Surprisingly little research exists regarding the enabling skills that students need to use word processors effectively. Numerous studies have examined the rate at which students acquire keyboarding skills (cf. Okolo et al., in press), but this line of research has shed minimal light on how keyboarding skills can best be taught or whether, beyond a minimal level, they are essential to effective word processing. Less attention has been paid to other enabling skills, such as knowledge of word processing functions (e.g., delete, move) or word processing components (e.g., spell checkers, thesauri).

An additional set of questions relates to the intersection of word processing and writing instruction. Extant research suggests that access to word processors should accompany instruction in the writing process (Graham and MacArthur, 1987; Morocco, Dalton, and Tinvan, 1989). Because student-computer ratios are not likely to decrease substantially in the near future (Becker, 1990a), pragmatic issues related to word processing use warrant investigation. What should be the balance of teacher-directed instruction, independent practice afforded by word processors, and other types of writing practice? How much access to word processing is necessary to make a difference in students' skills? How should instruction be organized so that students transfer the skills they learn in teacher-directed lessons to independent word processing tasks? How well do students transfer writing skills applied during word processing to paper-and-pencil tasks? How can teachers effectively distribute individual word processing time among a class of students?

A variety of computer-based programs have been developed to facilitate the process of writing. For example, pre-writing tools are available to help students choose topics, generate ideas, and focus on the audience for whom they are writing. Other tools, such as error checkers and reformatters, are designed to assist students in revising their compositions. To date, little is known about how these writing tools should be used. How effective are these programs and how can they supplement teacher-directed writing instruction? How can students be taught to use them effectively?

The role of multi-media environments in writing instruction is a final topic that is ripe for exploration. Hasselbring, Goin, and Wissick (1989) discuss the Multimedia Learning Lab; a prototype that combines text, video, digitized sounds, and synthesized speech. The writing component of the program permits students to enhance word processed compositions with sound, graphics, and video. Access to multi-media environments is purported to be provide a much-needed boost to reluctant writers' motivation. However, little is known about how students actually use these environments, how access to them should be structured so that they contribute to rather than detract from written expression, and how teachers can take advantage of their possibilities in the delivery of written expression instruction and practice.

How can design characteristics facilitate the use of word processing tools? At the present time, educators must choose from among a variety of word processing programs that operate in different ways and contain different functions. Word processing programs that are difficult for students to use can hardly be expected to facilitate their writing. With the exception of studies by MacArthur and Schneiderman (1984), however, few researchers have studied design characteristics that could facilitate disabled students' use of word processors. We do not know, for example, if menu-based or command-based systems easier for students to use. Nor do we know what types of help features are most easily accessed and most informative.

We also lack information about student interaction with word processing features such as spelling checkers, thesauri, and dictionaries. Dalton (1989) notes that typical spell checkers find only 60 percent of disabled students' spelling errors. What types of features could be added to spell checkers to alert students to other types of errors? When typical spelling checkers locate errors, they often require the user to correct them by choosing from among a list of words that appear highly similar. A student with spelling or decoding problems is unlikely to have the skills that would enable him/her to reliably discriminate among these words. How could spell checkers provide more informative feedback to students with reading disabilities? Similar questions could be raised about the design features of thesauri and dictionaries. The utilization of alternative or improved design features of word processing programs and their components would enable students to derive greater benefits from these tools.

How can instructional technology be used to encourage collaboration in the writing process? The opportunity afforded by technology for extending one's interpersonal communication network has generated substantial enthusiasm in the educational community. A number of instructional programs have utilized electronic networks and telecommunications to encourage student collaboration in the writing process. For example, the Computer Chronicles Newswire project links 3rd and 4th graders form Alaska to counterparts on California. Students publish a newspaper and, in this process, engage in dialogues with students from a different culture, learn to communicate clearly in writing, and evaluate and edit written composition (Reil, 1985). Another project, De Orilla a Orilla, links non-English speaking students from New England and California with Spanish-speaking students in Mexico and Puerto Rico to practice written communication skills (Sayers and Brown, 1987).

Although the optimism associated with collaborative writing projects has exceeded the data regarding their impact, some researchers have systematically documented positive effects on students' written products and motivation for writing (Daiute, 1986b; Daiute and Dalton, 1988; Riel, 1985; Weir, 1989). Not all collaborative projects are equally effective, however. Those that require students to engage in a joint activity and are characterized by the interdependency found in cooperative learning groups seem to have the best chances for success (Laboratory of Comparative Human Culture, 1989). At this point, little else is known about how to structure these tasks. What is their potential role in the writing curriculum? What features should they have? What types of enabling skills do students need before engaging in them? Given the social skill deficits common to students with disabilities, is social skill instruction a requisite component of collaborative writing programs? An additional issue of interest is the manner in which technology can support collaboration between disabled and non-disabled students in mainstreamed settings, subsequently facilitating the integration of disabled students in regular classrooms.

<u>What are the effects of using instructional technology to provide written expression instruction to students with disabilities</u>? As discussed in the previous scenario, investigation of instructional technology's impact should take place at multiple levels. Achievement should be gauged through dependent measures that assess both the

quantitative and qualitative aspects of written expression. Transfer of written expression skills to and from technology-based activities should be included in judgments of program efficacy. Experimental-control group contrasts should attempt to equate the quality of instruction between groups. Sufficient funding and time should be allotted so that researchers can not only institute and study the impact of technology-based interventions but also examine the manner in which these become integrated into the classroom curriculum and routine. Systematic observation, repeated interviews, and documentary analysis (e.g., teachers' schedules, students' written products) could provide important sources of data to inform these efforts.

Data also should be collected regarding the effect of word-processing and collaborative writing interventions on student motivation, perceptions, and attitudes. Increased student interest in writing and perceptions of self-competence may be among the most important advantages offered by word processing and collaborative writing experiences. Changes in teachers' and other students' perceptions also warrant investigation. These changes are of particular interest for students participating in collaborative writing experiences. Do these activities enhance a disabled students' competence, in the eyes of others? Do they facilitate acceptance? Or do they make the learner's disabilities more salient to others?

<u>What types of preparation and support do educators need to implement instructional technology in writing instruction</u>? As discussed in the previous scenario, answers to this question are crucial to the eventual impact of technology on instruction. Data should be collected regarding the types of hardware and software resources required to implement word processing and collaborative writing applications, with particular attention to cost. At the present time, many educators believe that expenses for telecommunication lines and connect time are prohibitive. More information about their actual cost/benefit ratio and ways to reduce their costs may help encourage their future use.

Finally, researchers should document the type of training teachers need to implement writing instruction that incorporates technology and teachers' emergent needs as technology becomes an integral component of the written expression curriculum.

Development: Technology-Based Tools for Writing Instruction

The production and field testing of additional technology-based applications and tools that provide procedural facilitation during the writing process, consequently teaching written expression skills, is recommended for the research agenda. As discussed above, technological tools have considerable potential to not only facilitate students' attainment of an outcome, such as a creative and error-free composition, but also to provide models for the attainment of that outcome that students can utilize in other activities and settings. Scardamalia, Bereiter, and Steinbach (1984) define procedural facilitation as a process in which explicit prompts are provided to help students adopt the metacognitive strategies used by sophisticated writers. Technology-based tools that provide procedural facilitation, such as prompted writing activities, writer's aids, and writing coaches, may not only help students produce better writing; they also may assist students to develop different models of the writing process. Consider outlining programs, which are designed to help writers interactively create and revise a written document. By displaying the contents of an outline at different levels of detail, a student may obtain different perspectives on the document, analyze part-whole relations, and experiment with alternative organizational schemes (Pea, 1985). Outlining may then become a strategy that students can apply to writing tasks in other settings or to other non-writing tasks that require students to organize information.

One can envision an assortment of tools that would prompt students to use more sophisticated writing strategies. These could range from a teacher-generated prompted writing task, entered as frozen text in a word processing program, to sophisticated, interactive programs that analyze students writing and provide on-line suggestions for improvement. Procedural facilitation could also consist of on-line writing strategy instruction, such as that provided by Englert et al.'s (1988) think sheets or Schumaker et al.'s (1985) error monitoring strategy. Principles of cognitive strategy instruction have yet to be widely exploited in technology-based writing programs.

III. RESEARCH THEMES FOR A THREE TO EIGHT YEAR AGENDA

Recommendations for a timeframe longer than three years are centered around two distinct themes. The first, technology and problem-solving instruction, focuses on ways that technology can be used to teach problem-solving skills within specific domains of instruction. The second, technology as distributed cognition, addresses ways in which technology can serve as a resource to enhance students' cognitive functioning. These two themes were reserved for the second timeframe not because they are less important than the first two topics, but in anticipation of continuing theoretical and technical advances.

The reader will note that the following two scenarios are briefer than the first two. Furthermore, potential topics and issues are described in less detail and are more often highlighted in a list of questions rather than explicated through examples of extant studies and applications. In contrast to the first two scenarios, there is less research upon which to base the final scenarios and fewer technology applications that can serve as prototypes. Given the rapidly evolving theoretical, empirical, and technical work relevant to these two themes, it is difficult to predict which issues and topics will be most important five to ten years from now. Although I believe that the issues raised by these themes can be productively explored through some combination of research and development efforts, only general themes are delineated.

A. Scenario 1: Technology and Problem-Solving Instruction

Almost every discussion of school reform includes proposals to teach problem-solving skills to America's students. Effective problem solving characterizes the performance of experts in many fields and is a high utility behavior that is likely to benefit students throughout their lifespan (Boyer, 1983). Depending on one's theoretical orientation, the term "problem solving" encompasses different behaviors. However, most educators agree that proficient problem solvers are adept at recognizing or posing problems, using or obtaining relevant information in an intelligent manner, allocating cognitive resources, and self-monitoring the problem-solving process (Brown, 1978; Schoenfeld, 1985).

Although problem solving-skills are widely acknowledged as an important goal, there is considerable controversy regarding the manner in which they should be taught. The advisability of teaching problem-solving skills as a set of general propositions that can be utilized across domains versus situating problem-solving instruction within a specific domain is one hotly debated issue (cf. Perkins and Salomon, 1989). Another controversy centers on the amount of external structure that should be provided during problem-solving instruction. Some educators advocate an externally-controlled sequence of activities that exposes students to progressively more complex tasks. Other educators cede control of the instructional environment to the learner, permit him/her to explore potential problems and discover their solutions, and provide external structure or guidance only as needed (Glaser, 1990).

Controversies aside, there is general agreement that instruction should entail the active application of problem-solving skills in the context of specific problems (Glaser, 1990). Students need ample opportunity to pose, implement, and observe the outcome of alternative problem solutions. Although the relative role of each is widely debated, most researchers would agree that problem solving entails a combination of general, heuristic strategies (e.g,. Bransford and Stein, 1984), domain-specific strategies (e.g., Gick, 1986), and domain-specific knowledge (e.g., Greeno, 1980). Researchers are paying increasing attention to the problem of "inert knowledge" (Whitehead, 1929), in which learners fail to solve problems because they do not realize that their existing knowledge and skills can be appropriately applied in a variety of different contexts (Anderson, 1987: Simon, 1980). Finally, there is considerable evidence that disabled learners are more likely to benefit from problem-solving instruction that includes the explication and modeling of appropriate strategies (Glaser, 1990; Swan and Black, 1987; Woodward and Carnine, 1988).

Problem-solving and simulation software programs have been developed to provide computer-based practice in problem solving. Examination of any computer software catalog will confirm that these are popular titles. Problem-solving and simulation activities are purported to help students develop a broader and more meaningful representation of the problem space and the range of appropriate solutions, facilitating the production of mental maps or schemata that can guide future problem-solving activities (Gorrell, 1990). However, studies of problem-solving and simulation software have produced mixed results (Duffield, 1990; Gorrell, 1990). Rather than developing a problem-solving schema, Gorrell (1990) found that positive outcomes associated with simulation software were due to practice effects. Students learned the concepts they practiced while using the program but did not develop an overall problem-solving strategy. These results support Woodward and Carnine's (1988) contention that simulation and problem-solving programs do not necessarily help students integrate a set of isolated facts into a theory or model of a domain.

Moreover, disabled and nondisabled students alike often fail to "discover" efficient or effective problem-solving strategies in the discovery-oriented approach that characterizes many problem-solving software programs. In fact, Duffield (1990) reports that some of the most commonly used problem-solving programs permit students to solve problems more quickly and successfully by using less rather than more sophisticated strategies. Effective problem-solving and simulation software programs often contains considerable learner guidance and support, such as elaborated feedback, modeling of explicit strategies for solving a simulation, and guided practice (Woodward et al., 1986; 1988).

Videodisc macrocontexts can permit teachers to provide problem-solving instruction in problem-oriented contexts that approximate real life situations and conditions (The Cognition and Technology Group at Vanderbilt, 1990). Problem-solving instruction that is anchored in realistic problem contexts is purported to help avoid the development of inert knowledge by demonstrating that information is relevant to a variety of different subjects and situations (Bereiter, 1984: Bransford and Vye, 1989). Video representations of problems are purported to enable students to form rich mental models of problem situations (McNamara, Miller, and Bransford, in press). Preliminary research with a videodisc macrocontext approach at Vanderbilt University has produced encouraging results. However, the Vanderbilt researchers have noted that students, at least in the initial stages of instruction, require teacher guidance and mediation to successfully formulate and structure problem-solving activities (Van Haneghan et al., in press; Young et al., 1990).

Research: Problem Solving Skills and Instructional Techniques

At this time, it seems most productive to require researchers to identify a content-area in which they will study problem solving. Although considerable debate still exists regarding the appropriate locus of problem-solving instruction, situating problem solving research in a particular domain has a few advantages. First, studies of technology integration suggest that technology-based problem-solving instruction has a higher probability of acceptance if it is aligned with an existing curricular area such as mathematics, science, or social studies. Second, because students with disabilities often need more intensive instruction, special educators are compelled to prioritize their educational activities. Problem-solving instruction has a greater chance of remaining a component of a student's curriculum if it is tied to a content-area subject than if it is viewed as a separate activity that competes for time in an already crowded curriculum.

Findings from the studies can improve educational opportunities for students with disabilities by generating information about the provision of effective problem-solving instruction in a variety of content areas. Although there is a voluminous and continually evolving body of research on problem solving, it has yielded few practical guidelines that can assist educators to effectively implement problem-solving instruction as a component of the curriculum. Formats such as videodisc macrocontexts and simulation software may make it more feasible for teachers to deliver effective problem-solving instruction. Finally, the empirical research that the recommended competition would support has the potential to significantly advance theories of learning and problem solving. To date, most recommendations for problem-solving instruction have been based on analyses of the skills and behaviors exhibited by expert problem solvers and cannot account for the steps that novices must take to become experts (Glaser, 1990). Instructional guidelines that focus on the end performance of experts, rather than the acquisition sequence necessary to become an expert, may be misleading or inefficient. Systematic study of various approaches to problem-solving instruction, such as those supported by this competition, would provide researchers with the opportunity to validate existing theories of problem solving or develop better ones (Ferretti and Belmont, 1983). The following questions are potential topics that could be addressed by the recommended research competition.

<u>What skills and behaviors constitute effective problem-solving behavior in a specific domain</u>? Because it is recommended that researchers situate their studies in a particular domain or content-area, initial research activities should entail the delineation of the skills or behaviors that are necessary to effectively solve problems in that domain. As discussed above, analyses of expert performance may be misleading, especially if this is the only information source used to identify problem-solving skills and behavior. Woodward et al., (1988) recommend that researchers conduct a careful analysis of the content domain, with particular attention to the background knowledge required to be effective in that domain and how it is sequenced. Additional data sources could include observations and interviews with students who are at various stages of proficiency, teacher interviews, and analyses of students' problem-solving products.

<u>How can students acquire the domain-specific knowledge and strategies necessary for effective problem solving</u>? One of the

distinguishing characteristics of expert problem solvers, in contrast to novices, is their domain-specific knowledge. This knowledge is the foundation upon which domain-specific strategies and schemata are built. What is the most effective way to inculcate students with the requisite domain-specific knowledge? Extant research in basic skill acquisition delineates highly effective instructional routines for helping students practice a prespecified set of facts or concepts to automaticity. However, other research suggests that such practice leads to the development of inert knowledge (The Cognition and Technology Group at Vanderbilt, 1990). How much domain-specific knowledge is necessary before students can apply this knowledge to problem-solving activities? What are the relative roles of general and domain-specific problem solving strategies? How are these strategies best acquired? Should they be practiced in highly-structured environments as subcomponents or should they be practiced as they are embedded in a complete problem-solving task (Glaser, 1990)?

<u>How much structure and guidance should be provided during problem-solving instruction</u>? Although educators disagree about the amount of external structure that should be provided during problem-solving activities, existing evidence suggests that some guidance and mediation from a teacher or external agent is necessary for learners to acquire effective problem-solving strategies (Clements, 1986; Delclos, Littlefield, and Bransford, 1985; Lehrer, Guckenberg, and Sancilio, 1988). But how much structure is optimal at various stages of the learning process? At some point, control over the problem-solving process must be transferred to the student. At what point should this occur? What conditions or features of instruction are necessary to ensure that students develop the self-regulatory mechanisms necessary for independent problem solving?

<u>What types of technology-based activities are effective for supporting and providing instruction in problem-solving skills</u>? As discussed above, the types of information and instruction that can be provided through computer and videodisc technology may enable educators to provide problem-solving instruction in new and more efficient ways.

Simulation and problem-solving software programs and videodisc macrocontexts are two promising examples. Educators also are optimistic about the parallels between the skills needed to organize, maintain, and access databases and those required for effective problem solving (OTA 1989). A number of questions about the feasibility and efficacy of technology-based activities remain unanswered, however. How can technology applications help students acquire the domain-specific knowledge they need to become proficient problem solvers? What types of practice in problem-solving strategies can technology provide or facilitate? What types of procedural facilitation could technology-based activities provide for learners as they make the progression from novice to expert problem solver? Under what conditions can technology-based activities help students to acquire generalizable problem-solving schemata rather than sets of discrete and unconnected facts?

One of the purported advantages of videodisc technology is its ability to provide a rich, realistic environment in which problem solving can be situated. What types of environments are optimal for problem-solving instruction and how can these be provided or represented through technology? Problem-solving and simulation software could be a cost-effective way to provide problem-solving instruction. Could its efficacy be enhanced through alternative design features or teacher mediation? What types of features should be built into technology-based problem-solving instruction to enhance the transfer of skills and strategies to novel problems and contexts?

<u>How can technology-supported problem-solving instruction be integrated into content area subjects</u>? The integration of problem-solving instruction with content-area subjects such as mathematics or social science makes it feasible for problem-solving activities to become an integral part of the curriculum. In fact, problem-solving instruction has the potential to transform content-area instruction from a focus on facts pertinent to discrete domains to the investigation of problems that cut across domains. Technology-supported problem-solving instruction offers promise for enhancing

collaborative learning and authentic activity in the classroom, mirroring the types of activities that students will engage in as independent citizens and adult workers (Brown, 1990; The Cognition and Technology Group at Vanderbilt, 1990). However, little is known about the conditions under which problem-solving instruction can be integrated into the curriculum; particularly when teachers face severe time and resource constraints and are held accountable for standardized achievement test scores. Systematic and extended examination of technology-supported problem-solving instruction as it occurs in classroom settings is needed to delineate the factors that facilitate its integration and efficacy. Issues such as hardware and software requirements and costs, compatibility with curricular or individual goals, administrative and technical support, and teacher preparation warrant investigation.

How should problem-solving instruction be structured to facilitate transfer of knowledge and skills? The issue of transfer is at the heart of problem solving research. If students can solve only the problems they have encountered during instruction, problem-solving activities have limited utility. Generalization of knowledge and skills to new problems and varied contexts is the ultimate goal of problem-solving instruction. Extant research indicates that problem-solving instruction is often successful in obtaining near transfer, in which students are able to transfer their expertise to new problems that are similar to the ones they have practiced. Far transfer, in which students utilize their skills and expertise in new problem-solving domains or on problems that have different characteristics, is dependent on the development of a mental map or schema that students can "transport" from one context to another (Salomon and Perkins, 198C). Far transfer is difficult to obtain, particularly for student with disabilities (Burton and Magliaro, 1987-88; Ferretti and Belmont, 1983). As discussed earlier, whereas problem-solving and simulation software is purported to help students achieve far transfer, Gorrell's (1990) research suggests otherwise. Under what conditions can problem-solving instruction facilitate far transfer? For students with disabilities, the amount of external structure and guidance provided may be critical for developing schemata. Moreover, extensive amounts of practice may be necessary to develop both near and far transfer. In fact, some researchers attribute the dismal results obtained in problem-solving studies to their short-term nature (Palumbo, 1990). How much practice or experience do students require to transfer skills from one context to another?

Even if students <u>have</u> developed the structures necessary to achieve far transfer, they may not do so because they fail to retrieve the appropriate information or strategies in a given situation. As discussed earlier, further research is needed that investigates how problem-solving environments and activities can help students avoid accumulating knowledge that will remain inert. To date, this research has focused primarily on the incorporation of videodisc environments. What characteristics of these environments account for their advantages? Does their multisensory nature provide multiple retrieval paths or are students more motivated to attend to the novel instructional format they represent? The Vanderbilt researchers describe macrocontexts as realistic and complex environments. From a students' perspective, what constitutes a realistic environment? How much complexity is optimal and how much is overwhelming?

<u>How should the impact of problem-solving instruction be measured</u>? Problem-solving skills do not lend themselves to the traditional psychometric measures used to evaluate achievement in other domains. Researchers must devise new ways to measure not only how well students have learned a particular task but also whether they can appropriately apply information and strategies to new settings and situations. Gaining access to students' strategies and schemata poses formidable challenges, particularly when the verbal protocol methods often used in problem-solving research may be inappropriate for students with expressive language disabilities. Researchers also may wish to pay more attention to the effects of problem-solving instruction on student variables such as self-efficacy, attitudes toward specific instructional domains, or willingness to participate in classroom activities.

The development and validation of appropriate and reliable measures of the impact of problem-solving instruction requires concerted attention. Technology represents a viable medium for presenting new problem situations and analyzing patterns of student responses; thus, it may assist researchers in their quest for appropriate and sensitive measurement strategies.

B. Scenario Two: Technology as Distributed Cognition

Rather than viewing intelligence as an entity that resides solely in the mind of an individual, many contemporary views of teaching and learning conceptualize intelligence as distributed across the individual and his/her environment (Pea, in press). Intelligent behavior is a function not only of a person's own capabilities but also of his/her interaction with others and with the tools available to him/her. Perkins (1990) refers to the physical and social resources that lie outside the individual but participate in cognitive activity as the surround.

Theories of distributed intelligence are consistent with many of the practices in which special educators engage. Modifications to the instructional environment to accommodate an individual learner's characteristics, characteristic of many IEP recommendations, are attempts to facilitate intelligent behavior by enhancing the surround. Providing a student with math facts tables that can be used during math tests or teaching a student how to list his/her homework on an assignment sheet at the end of each class period are examples of interventions that enhance the surround and consequently facilitate more intelligent behavior.

Many assistive technology devices function as tools that enhance human cognition by improving the learner's surround. To date, however, instructional technology has tended to focus on the learner him/herself, rather than the surround. Instructional technology applications, including most CAI programs, are designed to help learners acquire information in a more efficient or effective manner. They focus on getting information into the learner's head, rather than on how that information might be represented in tools to which the learner has access. Advances in hardware and software development provide a fortuitous opportunity to devote more attention to the use of instructional technology as a resource for distributed cognition.

Technological devices including computers, video cameras, VCRs, TVs, phones, and fax machines continue to become smaller without sacrificing their power or sophistication. Functions that were once relegated to separate devices are now combined in all-purpose appliances (D'Ignazio, 1990). The current obsession with graphical-user interfaces is a harbinger of technology systems that are more transparent and easier to use (Colvin, 1990). With the decreasing costs of mass-storage devices such as CD-ROM and hard drives, more information can be stored at less expense (Edyburn, 1990). These factors can make technology more accessible in a wider variety of settings for a wider variety of purposes that support human cognition.

Increasingly, we rely on technological tools to help us function in more intelligent ways. For centuries, external aids such as appointment calendars and address books have enabled us to record and retrieve information that would exceed our own memory capacities. Technological tools such as electronic organizers now permit us to place calendars, schedules, addresses, and reminders in one device, easing not only the weight of a purse or suit pocket but also facilitating retrieval of important personal information. Manufacturers now produce software cards that equip electronic organizers to keep track of expenses, compute scientific equations, and translate languages. Technological devices such as these can play an extremely important role in the day-to-day activities of students with disabilities. They can circumvent memory limitations, supply important background information, facilitate self-monitoring and goal setting, and support students in their efforts to organize and schedule their activities. By embodying the tools and knowledge that we need to function successfully in varying environments, these devices have the potential to help all of us behave in more intelligent ways.

<u>Development and Evaluation of Technological Tools to Support Cognitive Activities</u>

In order for technology to live up to this potential, however, there are a number of important issues that warrant explication. Returning to the view of cognition as distributed, and technology as one of the resources that supports intelligent behavior, a number of interesting questions must be answered about how knowledge can best be represented and accessed in technological devices. The development and evaluation of new technological devices or applications that support cognitive activities is recommended for a research agenda. Formative evaluation of these devices, or knowledge systems, should be a substantial component for development activities. One issue of particular concern should be the problems posed by miniaturization; although smaller devices are more portable, they may unduly restrictive for students with sensory or physical disabilities (Edyburn, 1990). Moreover, sufficient resources should be available to enable developers to examine how these knowledge systems are used in the environments for which they are intended.

Questions delineated below could provide technological tools that would compensate for students' disabilities and enable them to function in more intelligent and adaptive ways. If students can have ready access through technology to content area knowledge and procedures, educators can spend less time inculcating factual information and more time addressing higher-order skills. Students with disabilities can participate effectively in a wider range of educational and vocational environments and derive more benefit from the opportunities these environments offer. In fact, the knowledge systems developed may aid a broad cross-section of individuals, including educationally disadvantaged students and the elderly. By appealing to a broader audience, a system could be marketed at lower cost and thus be more feasibly supplied to any student whom it would benefit.

What kind of knowledge should be represented in technology-based systems? Developers must consider the type of knowledge needed to perform a specific task or to function in a particular environment and how this knowledge should be represented. It would be inadvisable to situate all knowledge in technology-based systems. Devices fail, and students may not always have access to a particular system. Moreover, some knowledge is more efficiently represented in person's head. The best spell-checking program appears cumbersome and sluggish when compared to a proficient speller's retrieval of a word's correct spelling. Technology has yet to approximate the efficiency and reliability with which humans can access the decoding rules and spelling patterns they have automatized. Perkins (1990) recommends that higher-order knowledge that is used repeatedly, such as domain-specific problem-solving strategies and patterns of inquiry that characterize a domain, should reside in the learner rather than technology-based devices.

However, other types of knowledge may be most efficiently represented in technology-based systems. The electronic organizer described above could constitute a _personal_ knowledge system that enables a student to store personal information such as home address and phone number, class schedule, and homework reminders (Edyburn, 1990). Hirsch (1987) championed the concept of "cultural literacy;" a corpus of shared cultural information that can facilitate literacy and promote effective communication. He has published a list of 5,000 names, dates, terms, and concepts, of which he recommends students have at least some superficial knowledge. Facts and concepts such as those contained in Hirsch's list are candidates for a _general information_ knowledge system that could enhance students' reading comprehension. Disciplines such as science or mathematics have their own specialized set of concepts and vocabulary that could be situated in _content-area_ knowledge systems. These systems could aid students with reading or vocabulary disabilities, experiential deficits, and/or memory limitations. As Edyburn (1990) points out, personal, general, and content-area knowledge systems cannot remain static but must accommodate updates and modifications to their knowledge bases.

A variety of other systems could be developed that would contribute to intelligent functioning in specific settings or activities. One can envision expert systems that analyze information to help students make decisions or procedural supports to assist students with problem-solving tasks and strategic behavior. These examples only hint at the potential resources that could be available to learners through technology-based systems.

How can knowledge be represented so that it is optimally useful for a learner? The manner in which knowledge is represented in a technology-based system can facilitate the ease with which it is retrieved, the efficacy with which it is used, and ultimately, the contribution it makes to a learner's understanding or skills. If a student cannot easily access the knowledge contained in a system, then it will not be used to its full potential. Sophisticated word processing systems provide a relevant example. The majority of users take advantage of only a fraction of the features that these programs contain. Undoubtedly, some features such as outlining, concordance generation, or mail merge, are not essential to the basic writing tasks that comprise most word processing use. However, many features are never accessed because users cannot remember how to invoke them or find them difficult to use. Other potentially useful features remain dormant because users do not realize how helpful they could be. Often, these features are represented or documented in a way that obscures their applicability to a particular situation or context. Developers of technology-based knowledge systems must consider how knowledge can be represented so that learners can both appreciate its uses and easily retrieve it on command.

An additional issue for consideration is the manner in which knowledge representation can contribute to a students' ultimate understanding of a task or domain. Representations such as concept maps may help a learner discern relationships among main ideas and details in a text. Graphs can assist learners to perceive mathematical relationships or patterns among different data sources. Non-disabled learners are more adept at representing knowledge in ways that facilitate their understanding and subsequent recall than are learners with disabilities, who often need assistance in developing appropriate and optimal representations (Gertner and Stevens, 1983; Mayer, 1989; Perkins and Unger, 1989). Multimedia technology may offer a rich source of multiple representations that can facilitate students' understanding and achievement.

<u>What type of instruction has to be provided in conjunction with knowledge systems to ensure their optimal use</u>? If students are to benefit from the opportunities that are afforded by technology-based knowledge systems, they will need instruction in their use. Students may need enabling skills, such as keyboarding facility or knowledge of hardware operation, to use these devices. What enabling skills are required and how can they be taught? Undoubtedly, most knowledge systems will assume that learners have some level of prerequisite knowledge or experience with the domain or environment in which they will be used. What are these prerequisites and, if a learner lacks them, how can they be acquired? As discussed above, learners may not take advantage of all a system's features because they don't realize how these features apply to a particular situation or task. How can teachers "lead students to the opportunities" that technology as distributed cognition can provide (Perkins, 1990)?

Another set of questions relates to how students can be taught to provide themselves with the optimal surround. In the technology-rich world of the future, students may be required to make decisions about which technology system to use and how to modify it to meet individual needs or the demands of a situation. Students also will need to decide when other resources, including teachers, peers, and print materials, are more advantageous than technology-based systems. How can teachers and perhaps knowledge systems themselves teach students to make these decisions autonomously?

<u>What impact do technology-based knowledge systems have on student achievement, attitudes, and independent functioning</u>? A broad range of tools and applications could be developed through the proposed competition. Consequently, these systems could produce a variety of student outcomes. Developers must delineate dependent variables that are appropriate to the purposes of a system and the environment in which it will be used. It seems reasonable to expect that "successful functioning" within a domain or environment would be a primary dependent measure in most efforts. Successful functioning could be defined as academic achievement, increased self-monitoring, or enhanced

acceptance by peers, depending on the purposes for developing and implementing a particular system. Attempts should be made to compare the degree to which students can function successfully with and without the knowledge system.

Other outcomes that warrant examination would most likely include students' attitudes, students' perceptions of a knowledge system, and students' beliefs about their self-efficacy with and without the knowledge system. Finally, in cases where a knowledge system may subsequently be used a cognitive tool, developers should examine how the procedures or knowledge embodied in the device are generalized to other circumstances and tasks.

What impact do technology-based systems have on teaching and learning? The concept of distributed cognition introduces subtle but profound changes in traditional views of the teaching and learning process. Although the idea of providing technology to facilitate students' achievement and independent functioning hardly seems controversial, most special educators can tell stories of elementary school teachers who refuse to let students use calculators during math tests or high school teachers who do not permit students to use portable spell checkers in composition class. Rather than bearing ill-will toward students with disabilities, some classroom teachers fear that technological tools will be used as a "crutch", preventing students from mastering knowledge that teachers perceive to be legitimate and important. Under what conditions will teachers accept the use of technology-based knowledge systems in the classroom? In what ways will teachers change their instruction when learners have access to these systems? What opportunities do students have while using these systems that they did not have prior to their availability?

The students' role in the instructional process also must be considered. Under what conditions will students want to use these systems? In particular, if utilization of technology-based knowledge systems differentiates disabled from non-disabled students, will students want to use these devices and will they do so effectively?

How will use affect their self-esteem, peer acceptance, and their teachers' perceptions of their capabilities?

As discussed earlier, technology not only changes the environment into which it is introduced, the environment changes technology as teachers and students appropriate it to their own goals (Newman, 1989). In what unanticipated ways are technology-based knowledge systems used in classroom settings? Do learners and teachers come to view these systems differently from the developer's initial intentions? Questions about the impact of the environment on the use of technology-based learning systems can only be answered through extended observation of the ways in which these tools are put to use in actual classroom settings over time.

ACKNOWLEDGEMENTS

I am grateful to Al Cavalier for his ideas on speech synthesis and compensatory technology, Ralph Ferretti for his conversations about problem solving, and Dave Edyburn for his visions of technology-based knowledge systems. I am solely responsible, however, for any over-simplifications or misinterpretations of the theory and research regarding these topics as presented in this paper.

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